



*An activity to help students learn about observation, interpretation, and argumentation*

————— **Gerald Rau** —————

In textbooks, much is said about the role of experimentation in science—but there is less about observation, and often little to nothing about inference or argumentation. The goal of science is not merely to describe an object or phenomenon, but to understand how the object was formed, or how and why the phenomenon occurs. Thus, it is necessary not only to collect data, but also to make and test inferences and convince other scientists that your interpretation is correct.

**FIGURE 1**

## Mystery box example.



**FIGURE 2**

## Sample mystery box objects.



In the activity described in this article, students are guided through four cycles of gathering evidence and making inferences about an object, initially hidden from view, during which they learn the value of data representations and collaboration. Instructions for conducting the activity and a rubric for scoring the assignment are also provided.

### Evidence versus inference

*Evidence* is obtained from empirical observation of objects or phenomena using our five senses. It can be gathered by our senses directly, or with the assistance of tools that extend our senses qualitatively or quantitatively. For example, using a microscope to see objects too small for our eyes is a qualitative extension—it improves the quality of what we are observing. Quantitative extension, on the other hand, involves the use of some sort of measuring device—a spectrometer to measure the wavelength of light is one example.

An *inference* is a conclusion, explanation, or judgment formed from evidence. There are two types of inferences: inductive and deductive. Inductive inferences (or induction) involve forming a rule from the evidence (i.e., a generalized conclusion from particular instances). This type of inference is responsible for most of the major breakthroughs in science. Deductive inferences (or deduction) involve categorizing or interpreting evidence based on a pre-existing rule (i.e., a conclusion about a particular instance that follows from a general premise) and therefore involves background knowledge. Both play a role in research, often

in the same investigation. For example, the size and shape of the DNA helix could be deduced from x-ray crystallography images, but inductive inference was needed to combine several lines of evidence to determine its structure.

Scientific argumentation requires that one know how to make decisions about which data to admit as evidence, state claims, and support those claims based on the evidence. In

the classical system of education, logic and rhetoric were core subjects. In our modern discipline-based orientation, however, these subjects are often marginalized to nonrequired classes, such as debate, so most students have very little exposure to the principles of argumentation. Current research in science teaching demonstrates the need to reverse this trend (Duschl and Osborne 2002).

**FIGURE 3**

## Steps for conducting the activity.

### Before step 1 (15 min.):

- ◆ Discuss the difference between evidence and inference.
- ◆ Explore examples of observations and inferences using a common object, such as a pencil.
- ◆ Explain that all the objects students will observe are of biological origin, although not all are organic.
- ◆ Divide the class into groups of two students each.
- ◆ Explain that all information the group discusses about one object will be recorded in one notebook, belonging to the student who first describes that object.

### Steps 1–9:

1. *Observation* (5 min.  $\times$  2 = 10 min.): One person feels the first object and describes the size, shape, surface features, texture, and density, while another records the observations in the laboratory notebook of the person doing the observation. Remember that the statements “this is made of...” and “this is” are not observations, but inferences. List instead the observations that lead you to infer that the object is made of a certain material. Switch roles and repeat the process for the other object in the box.
2. *Inference* (1 min.  $\times$  2 = 2 min.): Members of the group should work together to infer what each object is,

based only on the descriptions, and record their initial guess in the notebook.

3. *Representation* (3 min.): Each person should try to draw a picture of the object they observed, feeling it again if necessary.
4. *Inference* (1 min.  $\times$  2 = 2 min.): Groups should again try to infer what the object is. Is it easier now? Why?
5. *Collaboration* (3 min.  $\times$  2 = 6 min.): Now allow the other group member to feel the object. In a separate section, the person whose object is being described should record any additional observations.
6. *Inference* (1 min.  $\times$  2 = 2 min.): Try again to infer what each object is. Is it easier now? Why?
7. *Visual observation* (3 min.  $\times$  2 = 6 min.): Open the box, and examine each object visually. In a separate section, add to your description. What characteristics can you see that were not possible to observe by touch?
8. *Conclusion* (5 min.  $\times$  2 = 10 min.): Groups should again try to infer what the object is. (**Note:** Try to make your inferences as thorough and complete as possible. For example, rather than simply describing an object as a “bone,” try to identify the type of bone, the organism it may have come from, the biological classification of the organism, and so on.) If you are not exactly sure what the object is, can you at least place it in a kingdom? What background information are you drawing on to make that identification? What further information would you need to be sure of your identification? How did it get to the form it is in now? Was it modified after it stopped growing?
9. *Reflection* (5 min.): Discuss how this lab is similar to the process of scientific investigation. What are the roles of finding additional evidence, and of collaboration? Many of the objects are not complete, or are changed in some way since they were alive, making identification harder. How is this similar to real scientific investigation?



**FIGURE 4****Grading rubric: Process of science.**

Name:

Category	4 (Exceeds expectations)	3 (Meets expectations)	2 (Partially meets expectations)	1 (Does not meet expectations)
<b>Results</b>	Observations are presented clearly and accurately; they are organized logically in both table and written form in a way that makes it easy to follow and to form a mental image of the object, even without the picture.	Observations are presented accurately and organized in a logical and easy-to-read format that makes it easy to picture the object.	Observations are presented accurately, but format is hard to read, or there is insufficient data to form a mental image of the object.	Observations are incomplete or unclear.
<b>Discussion</b>	All inferences are in the discussion section, the process of refining the identification of the object is clearly explained, and the argument is clearly supported.	All inferences are in the discussion section, including the proposed identity of the object, which is clearly supported.	All inferences are in the discussion section, but the conclusion is not clearly supported, or some of the inferences are in the results section.	Data and inferences are not placed in separate sections of the report.
<b>Reflection: Process of science</b>	Describes how the process of the lab is similar to a scientific investigation, including the roles of sequential data collection and collaboration, with specific examples.	Describes how the process of the lab is similar to a scientific investigation, including the roles of sequential data collection and collaboration.	Describes either the role of sequential data collection or collaboration, or mentions both but does not relate them to scientific investigation.	Does not describe the importance of sequential data collection or collaboration.
<b>Reflection: Process versus reporting</b>	Explains how the report differs from the investigation itself, with specific illustrations.	Explains how the report differs from the investigation itself.	Mentions at least one difference between the report and the investigation itself.	Does not discuss the difference between the report and the investigation.
<b>Grammar and spelling</b>	There are no errors in spelling or grammar sufficient to distract the reader from the content.	There are a few errors in spelling or grammar that distract the reader from the content.	Most paragraphs contain errors in spelling or grammar that distract the reader from the content.	Errors in spelling or grammar make the paper difficult to read and understand.
<b>Headings and appearance</b>	Overall organization of the paper, including heading and subheadings, makes the paper easy to follow and visually appealing, with a creative title.	Overall organization of the paper, including heading and subheadings makes the paper easy to follow, with a descriptive title.	Heading or subheadings appear disorganized or in different formats, with a title.	Important portions of the heading or subheadings are missing.

## Mystery boxes

The “mystery boxes” activity described in this article was developed over the course of several years as an initial activity to refute the common misconception that science follows a single, universal method (AAAS 2009; McComas 2004). The activity facilitates an understanding of the nature of scientific inquiry and has been successfully implemented, with minor changes, in classes from middle school through college. Although developed as a biology exercise, with different objects, the same activity could easily be modified for use in Earth, life, or physical science classes.

In this article, the activity is used to help students learn about observation, interpretation, and argumentation. Students are led through several stages of observation and inference about an unknown object, during which they learn the value of representations and collaboration. They are then asked to construct an argument about the identity of the object and the process of its formation.

### Setup

It takes time to prepare for the activity the first time it is used, but subsequent setup time is minimal. First, prepare covered cardboard boxes to house the mystery objects. Each box needs to be large enough for an object to be placed inside and manipulated with one hand. Shoeboxes can be used for a single object. Paper or cardboard can be used to divide a larger box into two or four separate compartments, each of which holds a different object. In the top of each box, cut a hole the size of a fist, and cover the hole with a flap (Figure 1, p. 31).

Next, you will need to obtain one object per student. Choose objects students will not recognize easily, but that have identifiable characteristics. All objects should be produced by a once-living organism and modified in some way, either by natural or human activity. Some objects that have worked well include

- ◆ seashells or coral worn by the waves,
- ◆ dried sponges or seaweed,
- ◆ galls or growths broken from a plant,
- ◆ dried or worn corn cob or palm fiber,
- ◆ dried luffa or the rib of a cactus,
- ◆ a pine cone eaten by a squirrel or

run over by cars,

- ◆ the seed of a Norfolk Island pine or mango,
- ◆ the dried core of lettuce or skin of an avocado,
- ◆ a fossil or piece of bone (Figure 2, p. 31).

If you keep your eyes open on a trip to the beach or woods, you will find many suitable objects. Avoid anything students might not want to touch, including anything related to insects; be sure to thoroughly clean and

disinfect objects and make sure there are no sharp edges or other potentially dangerous surfaces. In a large class, two students may have the same kind of object, especially since no two will be identical.

### Introduction

Before beginning the activity, introduce the ideas of observation, inference, and argumentation, and describe their importance in science. Emphasize that this is not an experiment, since it does not have an experimental and response variable, and that experiments are not the only way science is conducted. It is good to check your vocabulary each time you conduct an activity, as many lab books mistakenly call any science activity an experiment, which creates confusion for students when they are later asked to design one.

I illustrate the difference between observation and inference by holding up a pencil and asking them to make observations about it. Usually students will identify it as a pencil, and often say it is made of wood, graphite, and other materials. I point out that these statements are inferences, based on background knowledge of the characteristics of certain objects or materials, and ask what led students to that identification. Gradually they see that descriptions such as “10 cm long,” “cone-shaped on one end,” “yellow,” and “smooth” are all observations, but statements containing “is a” and “made of” are inferences.

Unless you are on a block schedule or have a longer lab period, you will probably need to discuss this introductory material during one class period, and do the actual activity the next. This will allow enough time to complete the activity itself within one class period. I have found it works best to give the activity instructions to students one at a time, rather than



giving them a handout. This way they do not jump ahead to other steps until you are satisfied they have completed the requirements of the previous one (Figure 3, p. 32).

### Getting started

Instructions and suggested timing for the activity are shown in Figure 3, based on groups of two. This is suitable for most students. Groups of four can also be used, especially with younger or less experienced students. This allows for more interaction, input from other students, and ideas about what the object might be and how it came to be in its current state—but it also takes more time.

For step 1, I have found it useful to compile a list of suggested descriptive words, especially for texture, and have it available to students while they make their observations. Beyond *hard* or *soft*, *smooth* or *rough*, *stiff* or *flexible*, things can be *scaly*, *slippery*, *hairy*, *bumpy*, *silky*, *grainy*, *pebbly*, *squishy*, *spongy*, *spiny*, *leathery*, *fibrous*, *fragile*, *springy*, or a host of other adjectives. Depriving students of their sense of sight forces them to concentrate on details of texture they might otherwise overlook, and also makes this activity conducive to students with visual impairments. Make sure you circulate as students are working to ensure all statements listed are observations, and not inferences.

In the steps listed in Figure 3, the odd numbers involve observation, while the even numbers involve inference. This cycling makes students aware of the repeated cycles of data collection and interpretation in scientific inquiry. Step 1 emphasizes that observation in science does not necessarily involve vision. Step 3 highlights the importance of representations, in this case a picture, in visualizing data. Step 5 demonstrates the benefit of collaboration. By step 7, students are eager to see the object, eliciting excited cries of “I thought that was it!” and “What *is* that?”

### Reporting

Following the activity, students are asked to write a report, including sections on results, discussion, and reflection. All evidence should be listed in the results section; this includes

- ♦ a table of the observations, organized in an easy-to-follow format (students can use the five characteristics they were asked to observe as a guide for organizing their data);
- ♦ a redrawn figure of the object; and
- ♦ a written description that refers to both the table and figure, calling attention to important details.

In the discussion, students are asked to argue for the identity of the object and how it came to be in its

current state (was it broken, worn, crushed, or eaten?), supporting their argument with the evidence. In the reflection, they are asked to relate the lab activity to the way a scientific investigation is conducted, and to compare the order of obtaining information in the lab to the order of the final presentation.

Figure 4 (p. 33) shows a rubric handout for the students, including both background information and details of the assignment. The six categories assessed are results, discussion, two reflection topics, grammar and spelling, and headings and appearance. Students are not assessed on whether they identify the object and its formation correctly, but on how well they present their evidence and argue their conclusion based on the evidence.

### Conclusion

I use this activity within the first week of class to set the tone for the rest of the course. It introduces several important topics from the nature of science—a major theme in science education (Flick and Lederman 2006)—and helps prepare students for inquiry (NRC 2000) by teaching them to distinguish evidence from inference and how to construct scientific arguments. The gradual accumulation of evidence over the course of the activity helps students understand why scientific knowledge changes over time (AAAS 2009). It also stimulates their curiosity—they find themselves asking questions about their objects that will be answered later in the year. Not bad for one class! ■

Gerald Rau ([gerryrau@hotmail.com](mailto:gerryrau@hotmail.com)) is an independent scholar in Wheaton, Illinois.

### On the web

Process of science activity handout: [www.nsta.org/highschool/connections.aspx](http://www.nsta.org/highschool/connections.aspx)

### References

- American Association for the Advancement of Science (AAAS). 2009. Benchmarks online. [www.project2061.org/publications/bsl/online/index.php?chapter=1](http://www.project2061.org/publications/bsl/online/index.php?chapter=1)
- Duschl, R.A., and J. Osborne. 2002. Supporting and promoting argumentation discourse in science education. *Studies in Science Education* 38: 39–72.
- Flick, L.B., and N.G. Lederman, eds. 2006. *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education*. Dordrecht, The Netherlands: Springer.
- McComas, W.F. 2004. Keys to teaching the nature of science. *The Science Teacher* 71 (9): 24–27.
- National Research Council (NRC). 2000. *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.